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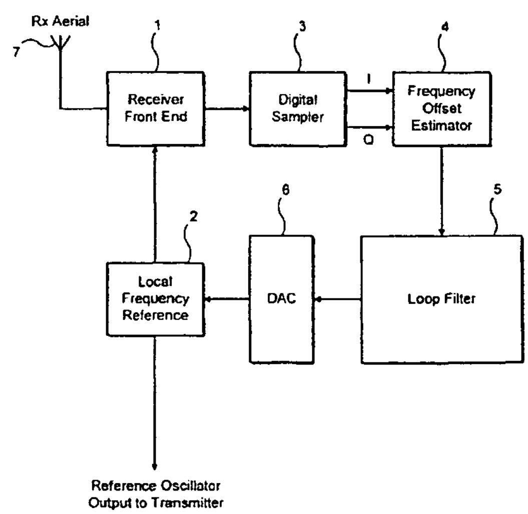



(57) **Abstract:** A method and apparatus for controlling a radio receiver provided with a local frequency reference (2) and a closed loop control system with a loop filter (5) for tuning the receiver's operating frequency to a received radio signal by altering the local frequency reference based on the received signal. On first receiving a radio signal from a given source, the characteristic of the loop filter (5) is fixed to a predetermined value. Subsequently, the characteristic of the loop filter (5) is changed after successive signal samples taken from the received signal so as to progressively increase the settling or alignment time of the receiver. Preferably the signal samples correspond to those portions of the received signal with a quality which exceeds, or alternatively equals or exceeds, a predetermined threshold value of signal quality. After a predetermined number of signal samples have been taken, the loop characteristic is fixed once more to provide a relatively slower settling time for the control loop.

WO 01/52412 A1

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# Radio Receivers

The present invention relates to a method of and an apparatus for tuning a radio receiver to the frequency of a received radio signal and in particular to a method of and an apparatus for tuning a mobile radio unit of a mobile radio communications system to the frequency of a received radio signal.

As is known in the art, radio receivers include a local frequency reference oscillator that they use as a frequency reference for synthesising their operating frequency, such as the local oscillator frequency, that is to be used (e.g. combined with) the received signal to allow the received signal to be properly processed in the receiver. (The local frequency reference will typically run at a frequency which is less than the operating frequency which is derived from it; for example, in mobile radio communications systems, the local frequency reference will typically be running at a frequency which is much lower than, e.g. 1/10th of, the synthesised operating frequency). To successfully process, e.g. demodulate a received radio signal, a radio receiver's operating frequency, e.g. local oscillator frequency, must be sufficiently accurately and appropriately aligned to, i.e. "tuned" to, the frequency of the received signal, so as to allow a suitable signal to be derived, else the processing of the received signal will be less accurate.

In many radio systems, it is also a requirement for a radio receiver to transmit at an accurately aligned frequency. For example, in the TETRA (TErrestrial Trunked RAdio) mobile radio system, a mobile radio unit is required to have its frequency of transmission closely aligned in terms of accuracy to the frequency of the signal it is receiving from its serving radio

station (e.g., base station, or, where the mobile radio unit is operating in direct mode (i.e. independently of a fixed radio network), direct mode master mobile station, or direct mode repeater or gateway), before it is permitted to transmit. The transmission frequency will be referenced from the mobile unit's local frequency reference.

In many radio receivers the local frequency reference will have a fixed frequency and the operating frequency will be derived by synthesising a frequency that is some multiple of the local frequency reference's frequency directly from the local frequency reference, e.g. by using a phase locked loop of some sort. In this case the operating frequency of the receiver will simply be set to be some multiple of the local frequency reference.

However, the Applicants have recognised that the accuracy of the operating frequency setting in this process is limited, *inter alia*, by the accuracy of the local frequency reference. While in many cases the local frequency reference may be sufficiently accurate, the Applicants have recognised that in some cases it may not be and that another means of setting the operating frequency may be desirable.

According to a first aspect of the present invention, there is provided a method of operating a radio receiver or transmitter having a local frequency reference whose frequency can be altered, and a closed loop control system for tuning the operating frequency of the receiver or transmitter using the frequency of the local frequency reference, the method comprising:

using the closed loop control system to alter the frequency of the local frequency reference based on the frequency of a received radio signal to tune the operating frequency of the receiver or transmitter.

According to a second aspect of the present invention, there is provided a radio receiver or

transmitter, comprising:

a local frequency reference whose frequency can be altered;

means for assessing the frequency of a received radio signal; and

a closed loop control system for tuning the operating frequency of the receiver or transmitter using the frequency of the local frequency reference and arranged to alter the frequency of the local frequency reference based on the frequency of a received radio signal to tune the operating frequency of the receiver or transmitter.

In the present invention, the operating frequency (local oscillator frequency) of the radio receiver or transmitter is based, *inter alia*, on the frequency of a received radio signal, rather than simply on an assumed to be accurate local frequency reference. This has the advantage that the received signal is likely to be coming from a more stable and accurate source such as a base station and can therefore provide a more accurate base for the operating frequency than a stand-alone local frequency reference.

Furthermore, in the present invention, the local frequency reference itself is adjusted to vary the operating (local oscillator) frequency based on the received radio signal. This has the advantage that the control process effectively causes the local frequency reference of the radio receiver or transmitter to be aligned with the current received signal source (e.g. base station). This should mean that the radio receiver/transmitter should be able to transmit to and receive from that signal source without further significant adjustment once "tuned", since its local frequency reference should be aligned to the frequency reference of the signal source, such that even if the signal source's frequency reference is in error, the local frequency reference of the radio receiver or

transmitter automatically takes account of that error (this could not happen where the local frequency reference is a stand-alone signal source).

In the present invention, when the operating (local oscillator) frequency of the radio receiver or transmitter is not initially aligned sufficiently with the frequency of the received radio signal the radio receiver's operating, local oscillator, frequency is tuned to set it appropriately relative to the frequency of the received signal. This can be done as desired, for example, by assessing the frequency of the received signal, estimating the error between the current local oscillator frequency and the desired local oscillator frequency for the estimated frequency of the received signal, and altering the radio unit's local frequency reference so as to alter the local oscillator frequency on the basis of the estimated error to try to set the local oscillator frequency more suitably for the received signal's estimated frequency.

This tuning process is carried out as a closed loop control process. The control loop preferably, as is known in the art, includes a loop filter to help control the performance of the closed loop system. As is known in the art, the loop filter affects the stability of the control loop, the extent to which errors in the tuning process may be introduced by noise, interference, and Doppler spreads, the extent to which errors in the received signal frequency assessment measurement affect the final accuracy, and the settling time of the loop (i.e. how long it takes the loop to settle (in the case of the present invention) the local frequency reference at a new, changed, frequency value, in response to a change in the received signal's frequency), etc. The loop filter is also normally used to set the dominant pole for the control loop and thus determines how rapidly the local frequency reference can change and what the final accuracy will be.

In radio receivers it is essential for the closed loop frequency control system to be stable (i.e. to settle to a final value, or to track the input stimulus in a predictable way), and desirable to minimise errors due to noise, interference, etc. Furthermore, for digital radio receivers where block processing is generally employed over any particular received timeslot in time division multiple access (TDMA) systems, it is also desirable to avoid rapid or large changes in the receiver's local oscillator frequency during a received timeslot. This is so as to reduce degradation of the radio receiver's performance by these factors. These requirements can usually be achieved by setting a relatively slow response characteristic in the loop filter.

It is also desirable for the radio receiver's local oscillator frequency to be tuned to the correct frequency at the permitted accuracy as rapidly as possible, i.e. for the system to have a fast settling time. This is particularly important where such frequency alignment is required before the radio can transmit, as more rapid frequency alignment permits the user to begin transmitting (e.g. making calls) earlier. The settling time of the system is determined, *inter alia*, by the loop filter, and thus a faster settling time can be achieved by setting the loop filter to have a faster response characteristic. However, as will be appreciated from the above, using a faster response time filter will result in a less accurate system.

This means that it can be difficult to select a single fixed characteristic for the loop filter that will provide a short alignment (settling) time, yet ensure that the control loop is sufficiently accurate. Thus using, as is typical in the art, a fixed response filter in the local oscillator tuning control loop in the present invention could tend to produce only a poor compromise between accuracy and a fast settling time.

The Applicants have recognised that this problem is exacerbated where the number of received signal bursts which can be sampled to estimate the received signal frequency (and thus used to apply a correction to the local frequency reference of the radio) in a given time interval will vary. For example, in the TETRA system, the number of signal bursts received by a mobile station can vary between 72 bursts per multiframe epoch (approximately one second) and only one burst every four multiframes, a ratio of 288:1. This makes it even harder to select a suitable characteristic for the loop filter, since the sample rate is effectively variable.

Thus, in a particularly preferred embodiment, when using the closed loop control system to tune the radio receiver's operating frequency to a received signal, the characteristic of the loop filter is varied during the processing of the signal from the signal source to provide the closed loop control of the local frequency reference by arranging the loop filter to have a particular filter characteristic when a radio signal from a given source is first received, thereafter during the signal reception changing the characteristic of the loop filter after each of N successive samples taken of the received radio signal, where N is an integer greater than zero, and fixing the characteristic of the loop filter for the remainder of the reception from the signal source once the N signal samples have been taken.

In this embodiment, rather than using a fixed characteristic loop filter in the local frequency reference tuning closed loop control system, the loop filter's characteristic is varied, by changing it after selected samples of the received radio signal, when the radio signal is initially received until a certain number of signal samples have been taken, at which point the loop filter's characteristic is fixed. In other words, the filter's characteristic is continually varied when a given signal is initially received and then fixed

for the remainder of the reception. This arrangement is believed to give an improved performance and results in a loop filter with effectively a different response for each of the N initial signal samples, but without the need to use a fully adaptive filter scheme.

It is believed that this arrangement is advantageous in its own right. Thus, according to a third aspect of the present invention, there is provided a method of operating a radio unit having a local frequency reference and a closed loop control system having a loop filter for tuning the radio unit's operating frequency to a received radio signal, the method comprising:

when using the closed loop control system to tune the radio receiver's operating frequency to a received signal, varying the characteristic of the loop filter during the processing of the signal from the signal source to provide the closed loop control of the operating frequency, wherein the varying of the loop filter's characteristic comprises:

arranging the loop filter to have a particular filter characteristic when a radio signal from a given source is first received;

thereafter during the signal reception changing the characteristic of the loop filter after each of N successive samples taken of the received radio signal, where N is an integer greater than zero; and

fixing the characteristic of the loop filter for the remainder of the reception from the signal source once the N signal samples have been taken.

According to a fourth aspect of the present invention, there is provided a radio unit comprising:

a local frequency reference;

a closed loop control system including a loop filter for tuning the operating frequency of the radio unit to a received radio signal;

means for varying the characteristic of the loop

filter during the processing of a signal from a given signal source to provide the closed loop control of the operating frequency, the varying means comprising:

means for arranging the loop filter to have a particular filter characteristic when a radio signal from a given source is first received;

means for, thereafter during the signal reception, changing the characteristic of the loop filter after each of N successive samples taken of the received radio signal, where N is an integer greater than zero; and

means for fixing the characteristic of the loop filter for the remainder of the reception from the signal source once the N signal samples have been taken.

In these aspects of the invention, the operating frequency is again preferably tuned by altering the local frequency reference of the radio unit based on the received frequency using the closed loop control system.

The initial characteristic that the loop filter is arranged to have is preferably predetermined, e.g. based on prior knowledge of the control loop's characteristics.

The way that the loop filter's characteristic is varied thereafter over the N signal samples can be selected as desired. The variation effected is preferably based on the known characteristics of the closed loop control system and the expected use conditions and desired operation of the system.

For example, the Applicants have recognised that in many radio systems, including the TETRA system, the radio receiver will be trying to gain alignment to a relatively very stable frequency reference (e.g. a base station), and once it has been able to remove the initial frequency error, it only needs to track relatively very slowly changing and small errors caused by noise, Doppler shifts, or reference drift. Thus there will be an initial settling period where a rapid response time is desirable, but thereafter accuracy will

be the only real concern.

Thus, in a particularly preferred embodiment, the loop filter is arranged to provide a relatively rapid response time to a given input change for the closed loop system when the signal is first received and for the first few signal samples thereafter, but thereafter the filter's characteristic is changed so as to increase progressively the system's response time as the number of samples increases. Preferably, the filter's characteristics are changed such that the system's response time always increases with each filter characteristic change.

The changes made to the filter's characteristic thus preferably depend upon the number of the signal sample from the start of the reception. In one preferred embodiment a filter characteristic is predetermined for each sample number, e.g. on the basis of the known characteristics of the control loop and the desired operation of the loop (e.g. a progressively increasing response time). Thus, for example, the characteristic to use could be predetermined for each sample number and then stored, e.g., in a look-up table, for use by the radio receiver. Alternatively, the characteristic for subsequent samples could be derived in a predetermined manner from the (e.g. predetermined) characteristic to which the filter is initially set. Preferably such derivation is dependent upon the sample number, for example by being proportional to n times or 1/n times the initial characteristic, where n is the sample number.

The characteristic which the filter is arranged to have could additionally or alternatively depend or be based on a parameter determined in relation to the received signal, such as the target settling frequency for the local frequency reference or the frequency error or offset indicated by a sample of the received signal. This may provide a more accurate system, but it requires

greater processing power and the Applicants have found that it is not necessary to use measured sample values to provide a suitable filter characteristic varying operation.

In such an arrangement, the new filter characteristic could be based on the current signal sample alone. However, it is preferably based on one or more, and most preferably all, of the preceding signal samples as well. Thus, for example, the weighted average of all the received signal frequency estimates for each signal sample up to and including the current signal sample could be taken, and that average used to estimate the target settling frequency and thus to select the new filter characteristic. In this arrangement, the estimated frequency of the first signal sample would be used to set the filter characteristic after receipt of the first signal sample, the weighted average of the estimated frequencies of the first and second signal samples would be used to set the filter characteristic after receipt of the second signal sample, the weighted average of the estimated frequencies of the first, second and third signal samples would be used to set the filter characteristic after receipt of the third signal sample, and so on, until the Nth signal sample, whereafter the filter characteristic is fixed.

The filter characteristic set after the N signal samples have been taken can also be selected as desired. It is preferably selected so as to cause the loop filter to effectively provide a relatively long-term sliding average of the estimated frequency error over a relatively large number of signal samples (e.g. 64 or the value of N), i.e. a relatively slow response time, in order to provide good rejection to noise, interference, errors in the frequency assessment and Doppler spreads, whilst still being able to track relatively low drift rates in the received signal's

frequency. This characteristic setting is preferably predetermined, e.g. on the basis of the known control loop characteristics.

Thus in the preferred embodiments of the present invention at least, during the initial adjustment phase for the loop filter's characteristic when a radio signal is initially received, the loop filter's characteristic is varied so as to provide a more rapid settling time for the initial signal samples, but the characteristic set after N signal samples have been taken (i.e. that the loop filter is then fixed at for the remainder of the reception) is chosen so as to try to provide greater accuracy. Thus preferably, the filter's characteristic is set so as to provide a more rapid settling time to the estimated target settling frequency for the first signal sample, to progressively increase the settling time over the next N signal samples, and thereafter set to provide a longer-term moving average of the received signal's estimated frequency. These arrangements have been found to provide a better compromise between achieving an initial rapid settling time, and longer term loop accuracy and insusceptibility to errors.

Thus, according to a fifth aspect of the present invention, there is provided a method of operating a radio unit having a local frequency reference and a closed loop control system having a loop filter for tuning the receiver's operating frequency to a received radio signal, the method comprising:

when using the closed loop control system to tune the radio receiver's operating frequency to a received signal,

when a radio signal from a given source is first received, setting the loop filter's response characteristic so as to provide a first, more rapid, settling time characteristic for the closed loop control system;

changing the response characteristic of the loop

filter so as to progressively increase the settling time of the system as the signal reception continues, until a predetermined number of signal samples have been received; and, thereafter,

fixing the response characteristic of the loop filter at a setting that provides a longer settling time for the control loop.

According to a sixth aspect of the present invention, there is provided a radio unit comprising:

a local frequency reference;

a closed loop control system including a loop filter for tuning the operating frequency to a received radio signal;

means for, when using the closed loop control system to tune the radio receiver's operating frequency reference to a received signal, when a radio signal from a given source is first received, setting the loop filter's response characteristic so as to provide a first, more rapid, settling time characteristic for the closed loop control system;

means for changing the response characteristic of the loop filter so as to progressively increase the settling time of the system as the signal reception continues, until a predetermined number of signal samples have been received; and

means for, thereafter, fixing the response characteristic of the loop filter at a setting that provides a longer settling time for the control loop.

In these aspects of the invention, the loop filter's characteristic is preferably varied as discussed above, e.g., in a predetermined manner on the basis of the current number of the particular signal sample from the start of the reception process, and *a priori* information about the open-loop characteristic of the frequency control system. Similarly, the operating frequency is again preferably tuned by altering the local frequency reference of the radio unit based on the

received frequency using the closed loop control system.

The number of signal samples, N, up to which the loop filter's characteristic is varied can be selected as desired. The value of N is preferably predetermined and preferably greater than one and most preferably greater than 32. A suitable value of N has been found to be 64 or 128.

The signal samples after which the filter's characteristic is changed can be selected as desired. They are preferably signal samples of a selected type. Where the received radio signal is received in discrete portions at intervals, e.g. it is a signal that is received in discrete time slots, e.g. selected, spaced, timeslots, such as a signal in a time division multiple access (TDMA) radio system, the selected signal samples could each comprise a single signal portion, e.g. a single timeslot, reception. In such an arrangement, they more preferably comprise each and every received signal portion (e.g. timeslot), i.e. such that the loop filter's characteristic is changed after the first and every subsequent signal portion (timeslot) reception for the signal until N signal portions (timeslots) have been received, whereafter the filter's characteristic is fixed.

In a particularly preferred embodiment the signal samples after which the filter's characteristic is changed comprise only signal portions (e.g. timeslots) which are determined to have been "well-received". The updating process will then continue until N "well received" signal portions have been received. Only using "well-received" signal samples can help to prevent, for example, signal receptions which are excessively noisy, have too much interference or too large an amount of fading, from degrading the performance of the control loop. For example, if the second signal burst (timeslot) from a new call (i.e. a new signal source) is excessively noisy, then it is

likely that a poor estimate of its frequency offset will be made and if this burst were to be included in the setting of the output of the control loop, then the result is likely to be worse than just using the good (first) burst alone. By only using "well-received" signal samples to provide the filter control, this problem can be avoided.

Where the loop filter's characteristic setting is based on a parameter, such as the frequency error, derived from a signal sample, the selected signal samples that the filter's characteristic changes are based on and made after similarly preferably comprise only "well-received" signal portions, for the same reason.

The decision as to whether a signal portion (e.g. timeslot) has been "well-received" can be made as desired. Preferably, a signal portion is determined to be "well-received" if its estimated signal quality equals or exceeds a given, preferably predetermined, threshold value. Thus preferably a measure of the received signal's quality is used to assess whether it has been "well-received". For example, a parameter representative of the quality of the received signal portion could be estimated and if that parameter equals or exceeds a predetermined quality threshold level, the signal sample considered to be "well-received". Any suitable signal quality parameter, such as the received signal strength could be used. Where possible, preferably the correlation of particular signal sequences, e.g. training sequences, in the received signal portion with reference signal sequences is used as the measure of signal quality. Other signal quality indicators, such as the variation of sampled parameter values for the received signal portion could be used as well or instead, if desired.

The characteristic of the loop filter should be set and changed in a manner appropriate to the filter in

question. Thus, for example, where appropriate, such as in a digital filter, the filter's characteristic is preferably changed and/or fixed by setting or updating its co-efficients to particular values, e.g. by deriving new or additional co-efficients based on the sample number.

The radio unit's closed loop control system should operate in the normal manner, subject to the changing characteristic of the loop filter during reception of the signal. Thus it will, for example, sample the received signal and use the signal samples to estimate the frequency error or offset between the radio receiver's current operating frequency and the operating frequency necessary to process the received signal and derive a correction (using e.g. past and present frequency error estimates) to be applied to the local frequency reference to tune to the received signal.

The signal samples used to provide control of the operating frequency and/or of the local frequency reference can be selected as desired. They could be the same signal samples as those samples after which the filter's characteristic is changed, but this is not necessary and any signal sample can be used to provide a frequency error estimate as an input to the control loop.

In a particularly preferred embodiment the signal samples used to provide control of the operating frequency and/or of the local frequency reference comprise only signal portions (e.g. timeslots) which are determined to have been "well-received", for the same reasons that the signal samples after which the filter's characteristic is updated are preferably only "well-received" signal portions (i.e. to, for example, help to prevent signal receptions which are excessively noisy, have too much interference or too large an amount of fading, from degrading the settling performance of the control loop). The decision as to whether a signal

portion (e.g. timeslot) has been "well-received" can be made as discussed above.

The present invention, in its preferred embodiments at least, effectively uses a relatively short response time characteristic loop filter during the initial signal reception phase. In such an arrangement, the control loop could try to apply a relatively large frequency correction to the radio unit's local frequency reference (depending on the frequency error) during this initial phase. Preferably, therefore, when operating the present invention in this manner, any derived frequency correction is applied when there is a gap in the signal reception. This is to reduce the possibility of relatively rapid changes in the radio receiver's local frequency reference's frequency being attempted during a period of continuous reception, as such rapid changes could adversely affect the processing of the received signal.

For example, in the case where adjacent-slot receptions are occurring at the beginning of a call assigned to a new base station after a cell-reselection, if the first time-slot were to indicate that a large frequency correction to be the local frequency reference was required, then using relatively rapid settling time filter coefficient values could cause the system to attempt to apply a relatively large frequency correction to the local frequency reference before the start of the second time-slot reception. If the open-loop settling time of the local frequency reference was too slow, then applying the update in this manner would cause the local frequency reference to drift during the second time-slot reception, which may result in the total loss of the signal in the second time-slot.

Thus furthermore, where it is determined that the radio receiver is receiving a continuous signal that does not have any gaps in it, for example in a trunked mode mobile radio system when a mobile radio unit is

using adjacent-slot reception (i.e. receiving a signal from the same source on adjacent time-slots) over all time slots, e.g. receiving a multi-slot data call in consecutive time slots, the loop filter's characteristic is preferably set to the characteristic providing a relatively slower response time to be used after N signal samples have been received (i.e. in the above preferred embodiments, to the final long term average rate characteristic) for the entire signal reception, rather than adjusting the loop filter's characteristic when the signal is initially received.

By using the fixed, long term average, filter characteristic in such a situation instead of a faster response time characteristic, the above problem of applying too large a frequency correction in too short a time can be avoided, but the local frequency reference will still eventually gain the correct frequency alignment.

Thus, for example, where adjacent-slot reception is occurring over all timeslots, the longer settling time filter characteristic is preferably used. However, if there is a gap in the reception, e.g. not all time-slots are being used for it, then the method of the present invention using a shorter response time filter characteristic can be used and at each reception gap the appropriate frequency correction applied, if desired, as this should not then detrimentally affect reception of the next signal burst.

Where it is necessary for the radio unit to be aligned to the frequency of the received signal for it to be permitted to transmit, such as would be the case in the TETRA system, the radio unit must be able to assess whether the frequency of its local frequency reference has been tuned within the required tolerance of the frequency of the transmitting station (as received at the radio unit's aerial). A direct frequency comparison will usually be impossible, as the

only frequency reference will be the local oscillator (which will typically be less stable than the frequency source being measured), and any frequency estimation scheme has potential for errors and inaccuracies. In a preferred arrangement therefore, the assessment of whether the frequencies are aligned is based on the correction to be applied to the local frequency reference by the closed loop control system. When that correction is less than or equal to a predetermined value (which could, for example, be the maximum tolerance or error in the radio unit's frequency that it is permitted to transmit at), it is assumed that the frequency of the radio unit is sufficiently aligned for it to transmit.

It is believed that this method of assessing whether the frequencies are aligned is new and advantageous in its own right. Thus according to a seventh aspect of the present invention, there is provided a method of operating a radio transceiver having a local frequency reference and a closed loop control system for tuning the transceiver's local frequency reference to a received radio signal, the method comprising:

when a radio signal is first received, using the closed loop control system to tune the radio transceiver's local frequency reference to the received signal; and

assessing whether the local frequency reference of the radio transceiver is sufficiently closely aligned to the received radio signal to allow the transceiver to transmit by comparing the correction currently to be applied to the local frequency reference by the closed loop control system to a predetermined threshold correction value.

According to an eighth aspect of the present invention, there is provided a radio transceiver comprising:

a local frequency reference;

a closed loop control system for tuning the transceiver's local frequency reference to a received radio signal; and

means for assessing whether the local frequency reference of the radio transceiver is sufficiently closely aligned to the received radio signal to allow the transceiver to transmit by comparing the correction currently to be applied to the local frequency reference by the closed loop control system to a predetermined threshold correction value.

The method of the present invention could be used to tune the local frequency reference of the radio receiver to a signal source whenever the radio switches to a new signal source on a different frequency.

However, where the radio receiver is returning to a signal source to which it has relatively recently tuned its local frequency reference and derived a settled (tuned) frequency offset which had to be applied to the radio's local frequency reference to bring it into alignment with that signal source, and it is known that that source will have a relatively high frequency stability over time (such as might be the case for a mobile radio system base station), the already derived frequency offset for that transmitter may still be valid, at least for a limited period of time. Thus, in a preferred embodiment the radio receiver stores the frequency offset derived for a particular signal source, and uses the stored frequency offset to tune to that particular signal source, if it returns to that signal source within a predetermined time period (which time period should be based on the estimated period of validity of the stored frequency offset).

It is believed that this may be a new and advantageous idea in its own right. Thus according to a ninth aspect of the present invention, there is provided a method of operating a radio receiver having a local

frequency reference, the method comprising:

storing the derived settled frequency offset which had to be applied to the receiver's local frequency reference to bring it into alignment with a given signal source, once the receiver's local frequency reference is satisfactorily tuned to that signal source; and, when the radio receiver returns to a signal source for which it has a stored settled frequency offset within a predetermined period of time since the stored frequency offset was derived, reapplying that stored frequency offset to its local frequency reference, rather than deriving a new frequency offset for that frequency reference.

According to a tenth aspect of the present invention, there is provided a radio receiver, comprising:

a local frequency reference;

means for storing the derived settled frequency offset which had to be applied to the receiver's local frequency reference to bring it into alignment with a given signal source, once the receiver's local frequency reference is satisfactorily tuned to that signal source; and

means for, when the radio receiver returns to a signal source for which it has a stored settled frequency offset within a predetermined period of time since the stored frequency offset was derived, reapplying that stored frequency offset to its local frequency reference, rather than deriving a new frequency offset for that frequency reference.

The period of validity of the stored frequency offset is limited mainly by the radio receiver's local frequency reference temperature drift, and is therefore preferably based on that drift. This can be assessed from a temperature measuring device and the known local oscillator temperature versus frequency characteristic (which may be known from, e.g., manufacturer's published

data, or may be assessed empirically by testing the oscillator).

The radio receiver of the present invention could be any such receiver. However, the present invention is particularly applicable to mobile radio systems and in particular to the operation of mobile radio units of mobile radio systems. For example, the characteristic of the oscillators used for base stations in mobile radio systems is usually of extreme accuracy and low rate of drift. For a TETRA direct mode master mobile station the accuracy and rate of drift are worse, but the drift rate is still relatively low (i.e. drift occurs over many seconds). Therefore, in both cases, tracking the drift of the serving transmitter is less of a problem than gaining the initial frequency lock. Since the method of the present invention can provide a more rapid initial frequency lock, it is therefore advantageous in these circumstances.

The present invention is similarly particularly applicable to the operation of mobile radio units of radio systems, such as the TETRA system, in which a mobile unit must align its frequency to the frequency of the transmitting station (e.g. base station or direct mode master) before being permitted to transmit, as it can permit more rapid synchronisation to the transmitting station.

The methods in accordance with the present invention may be implemented at least partially using software, e.g. computer programs. It will thus be seen that when viewed from further aspects the present invention provides computer software specifically adapted to carry out the methods hereinabove described when installed on data processing means, and a computer program element comprising computer software code portions for performing the methods hereinabove described when the program element is run on a data processing means. The invention also extends to a

computer software carrier comprising such software which when used to operate a radio receiver comprising a digital computer causes in conjunction with said computer said system to carry out the steps of the method of the present invention. Such a computer software carrier could be a physical storage medium such as a ROM chip, CD ROM or disk, or could be a signal such as an electronic signal over wires, an optical signal or a radio signal such as to a satellite or the like.

It will further be appreciated that not all steps of the method of the invention need be carried out by computer software and thus from a further broad aspect the present invention provides computer software and such software installed on a computer software carrier for carrying out at least one of the steps of the methods set out hereinabove.

A number of preferred embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawing, Figure 1, which shows schematically the frequency control system of a radio receiver.

The present invention will be described with reference to the operation of a mobile radio unit of the TETRA (TErrestrial Trunked RAdio) system. However, as will be appreciated by those skilled in the art, the invention is applicable generally to all radio receivers where it is necessary to tune the operating or local oscillator frequency of the radio receiver to the frequency of a received radio signal.

Figure 1 illustrates a closed loop frequency control system for tuning the local frequency reference 2 of a mobile radio unit to the frequency of a received radio signal.

In operation of the frequency control system, the radio front-end receiver 1 receives a radio signal from the aerial 7 and uses the frequency reference generated by the radio unit's local frequency reference oscillator

2 to downshift the received modulated carrier and provide a representation of the received radio signal in a suitable form for further processing.

The frequency error between the local oscillator frequency derived from the local frequency reference and the local oscillator frequency necessary to process the received signal is then estimated. This can be done in any suitable manner.

In the TETRA system, for example, the demodulated received signal could be downshifted to baseband and then digitally sampled to give a Pulse Code Modulated (PCM) representation of the baseband signal in in-phase (I) and quadrature phase (Q) streams by a digital sampler 3. The frequency estimation could then be made by digitally processing the IQ streams in a frequency offset estimator 4 to obtain an estimate of the total $\pi/4$ differential quadrature phase shift keying ($\pi/4$ DQPSK) modulation phase transitions as employed in the TETRA standard. By averaging these phase transitions over a complete burst period an average phase result can be obtained and the frequency error then found by comparing the expected phase with the estimated phase based on the 18k Baud transmission rate specified in the TETRA standard.

The frequency error estimates are then used to derive a correction to apply to the local frequency reference 2 to tune it to the received signal's frequency, as is known in the art. The correction is applied via the frequency control system control loop which includes a loop filter 5 whose output is then applied to control the local oscillator's frequency via a digital-to-analogue convertor (DAC) 6. The loop filter receives the frequency offset (error) estimates as inputs, filters the present and past frequency error estimates, as is known in the art, and a correction to be applied to the local frequency reference 2 is derived. The loop filter can be implemented as desired,

for example as a digital filter.

The operation of the closed loop control system in accordance with the present invention will now be described.

When the receiver first receives a new signal source (e.g. when a new base station or direct mode master is acquired), the receiver arranges the loop filter to have a particular characteristic by setting its co-efficients to a predetermined value or values. After each of the first N received signal bursts (a TETRA signal is received as a series of discrete signal bursts (timeslots)) following the start of the reception, the characteristic of the loop filter is changed by updating the loop filter's co-efficients. Once N signal bursts have been received, the loop filter's characteristic is fixed by fixing its co-efficients for the reminder of the reception from the signal source. The receiver can conveniently run a counter to count the N signal bursts, which counter is reset every time a new signal from a new signal source is received.

As discussed above, for the first N signal bursts when the signal is initially received, the filter's characteristic is changed based on the sample number and knowledge of the closed loop control system's characteristics, to provide initially a relatively rapid settling time with the settling time progressively increasing as the number of received signal bursts increases. The filter co-efficient values to use for each signal burst number could, for example, be predetermined and stored in a look-up table which is then used to select the appropriate filter co-efficient values. Thus the loop filter 5 performs a pre-defined coefficient update dependent upon the number of (preferably well-received) signal bursts collected from the relevant transmitter (e.g. base station or TETRA Direct Mode Master).

The fixed filter co-efficient values used for the remainder of the signal reception are preferably set so as to effectively provide a sliding average of the reported frequency errors or offsets over a large number of signal bursts in order to provide the usual benefits of rejection to noise, interference, errors in the frequency assessment and Doppler spreads, whilst still being able to track the low rate of drift the serving transmitter's reference oscillator.

As discussed above, preferably only signal bursts which are considered to have been "well received" are used to correct the local oscillator. Furthermore, the long-term sliding average filter characteristic value is preferably used where a continuous reception is being received.

Where it is necessary for the transmission frequency of the radio unit to be tuned to within a required tolerance of the frequency of the transmitting station as received in the mobile station's aerial (which tolerance could, for example, be +/- 2 ppm in the TETRA system) that assessment is preferably, as discussed above, carried out by looking at the correction being applied by the closed loop control system. The correction being applied can be determined in any appropriate manner. For example, it could be based on the loop filter output, using a knowledge of the loop forward characteristics, such as, in the present example, the number of bits per Hertz of the digital to analogue convertor 6 setting to the local frequency reference 2 frequency output.

Claims

1. A method of operating a radio unit having a local frequency reference whose frequency can be altered, and a closed loop control system for tuning the operating frequency of the radio unit using the frequency of the local frequency reference, the method comprising:

using the closed loop control system to alter the frequency of the local frequency reference based on the frequency of a received radio signal to tune the operating frequency of the radio unit.

2. The method of claim 1, wherein the closed loop control system includes a loop filter, further comprising when using the closed loop control system to tune the radio unit's operating frequency to a received signal, varying the characteristic of the loop filter during the processing of the signal from the signal source to provide the closed loop control of the local frequency reference, wherein the varying of the loop filter's characteristic comprises:

arranging the loop filter to have a particular filter characteristic when a radio signal from a given source is first received;

thereafter during the signal reception changing the characteristic of the loop filter after each of N successive samples taken of the received radio signal, where N is an integer greater than zero; and

fixing the characteristic of the loop filter for the remainder of the reception from the signal source once the N signal samples have been taken.

3. A method of operating a radio unit having a local frequency reference and a closed loop control system having a loop filter for tuning the radio unit's operating frequency to a received radio signal, the method comprising:

when using the closed loop control system to tune the operating frequency of the radio unit to a received signal, varying the characteristic of the loop filter during the processing of the signal from the signal source to provide the closed loop control of the operating frequency, wherein the varying of the characteristic of the loop filter comprises:

arranging the loop filter to have a particular filter characteristic when a radio signal from a given source is first received;

thereafter during the signal reception changing the characteristic of the loop filter after each of N successive samples taken of the received radio signal, where N is an integer greater than zero; and

fixing the characteristic of the loop filter for the remainder of the reception from the signal source once the N signal samples have been taken.

4. A method of operating a radio unit as claimed in claim 2 or 3, wherein the initial characteristic that the loop filter is arranged to have when the signal is first received is predetermined.

5. A method of operating a radio unit as claimed in claim 2, 3 or 4, wherein the characteristic of the loop filter is changed during the signal reception so as to progressively increase the settling time of the system as the number of signal samples increases until the N signal samples have been taken.

6. A method of operating a radio unit as claimed in claim 2, 3, 4 or 5, wherein the characteristic of the loop filter is fixed to provide a relatively slower settling time once the N signal samples have been taken.

7. A method of operating a radio unit having a local frequency reference and a closed loop control system

having a loop filter for tuning the radio unit's operating frequency to a received radio signal, the method comprising:

when using the closed loop control system to tune the radio unit's operating frequency to a received signal,

when a radio signal from a given source is first received, setting the loop filter's response characteristic so as to provide a first, more rapid, settling time characteristic for the closed loop control system;

changing the response characteristic of the loop filter so as to progressively increase the settling time of the system as the signal reception continues, until a predetermined number of signal samples have been received; and, thereafter,

fixing the response characteristic of the loop filter at a setting that provides a longer settling time for the control loop.

8. A method of operating a radio unit as claimed in any one of claims 2 to 7, wherein the initial filter characteristic set for the loop filter when the signal is first received is used to derive the loop filter characteristic set after each of the N successive samples taken from the received radio signal.

9. A method of operating a radio unit as claimed in any one of claims 2 to 8, wherein a parameter derived from the current received signal sample is used to derive the filter characteristic set after each given one of the N successive samples taken from the received radio signal.

10. A method of operating a radio unit as claimed in claim 9, wherein a parameter derived from one or more of the preceding signal samples is also used to derive the

filter characteristic set after a given signal sample.

11. A method of operating a radio unit as claimed in any one of claims 2 to 10, wherein the filter characteristic set after each of the N successive samples taken from the received radio signal is dependent on the signal sample number.

12. A method of operating a radio unit as claimed in any one of claims 2 to 11, wherein the radio signal comprises discrete signal portions, and the signal samples of the received radio signal after which the characteristic of the loop filter is changed comprise such signal portions.

13. A method of operating a radio unit as claimed in claim 12, wherein the radio receiver is for a time division multiple access (TDMA) radio system, and the received signal portions comprise time slots of the radio system.

14. A method of operating a radio unit as claimed in any one of claims 2 to 13, further comprising the steps of assessing the signal quality of samples of the received signal, comparing the signal quality with a predetermined threshold value, and wherein the signal samples after which the characteristic of the loop filter is changed comprise only those signal samples whose signal quality exceeds, or alternatively equals or exceeds, the threshold.

15. A method of operating a radio unit as claimed in any one of the preceding claims, further comprising the steps of assessing the signal quality of samples of the received signal, comparing the signal quality with a predetermined threshold value, and controlling the operating frequency or the local frequency reference of

the radio unit using only signal samples whose signal quality exceeds, or alternatively equals or exceeds, the threshold.

16. A method of operating a radio unit as claimed in any one of the preceding claims, wherein any correction derived for the operating frequency or the local frequency reference of the radio unit is only applied when there is a gap in the signal reception.

17. A method of operating a radio unit as claimed in any one of the preceding claims, further comprising the steps of determining whether the received signal is continuous, and, in response to a continuous signal, arranging the loop filter to have a fixed characteristic providing a relatively slow settling time for the entire duration of that signal reception.

18. A method of operating a radio transceiver having a local frequency reference and a closed loop control system for tuning the operating frequency of the transceiver to a received radio signal, the method comprising:

when a radio signal is first received, using the closed loop control system to tune the operating frequency reference of the radio transceiver to the received signal; and

assessing whether the operating frequency of the radio transceiver is sufficiently closely aligned to the received radio signal to allow the transceiver to transmit by comparing the correction currently to be applied by the closed loop control system to a predetermined threshold correction value.

19. A method of operating a radio unit as claimed in any one of the preceding claims, comprising the radio unit storing the frequency offset derived to bring the

receiver into alignment with a given signal source once the operating frequency of the receiver is tuned to that signal source, and, when the radio unit returns to a signal source for which it has a stored settled frequency offset within a predetermined period of time since the stored frequency offset was derived, reapplying that stored frequency offset to its local frequency reference.

20. A method of operating a radio receiver having a local frequency reference, the method comprising:

storing the derived settled frequency offset which had to be applied to the local frequency reference of the receiver to bring it into alignment with a given signal source, once the operating frequency of the receiver is tuned to that signal source; and

when the radio receiver returns to a signal source for which it has a stored settled frequency offset within a predetermined period of time since the stored frequency offset was derived, reapplying that stored frequency offset to its local frequency reference.

21. A method of operating a radio receiver as claimed in claim 19 or 20, wherein the predetermined time period is determined by the temperature drift of the local frequency reference of the receiver.

22. A radio unit, comprising:

a local frequency reference whose frequency can be altered;

means for assessing the frequency of a received radio signal;

a closed loop control system for tuning the operating frequency of the radio unit using the frequency of the local frequency reference and arranged to alter the frequency of the local frequency reference based on the frequency of a received radio signal to

tune the operating frequency of the receiver or transmitter.

23. A radio unit as claimed in claim 22, wherein the closed loop control system includes a loop filter, and further comprising means for varying the characteristic of the loop filter during the processing of a signal from a given signal source to provide the closed loop control of the local frequency reference, the varying means comprising:

means for arranging the loop filter to have a particular filter characteristic when a radio signal from a given source is first received;

means for, thereafter during the signal reception, changing the characteristic of the loop filter after each of N successive samples taken of the received radio signal, where N is an integer greater than zero; and

means for fixing the characteristic of the loop filter for the remainder of the reception from the signal source once the N signal samples have been taken.

24. A radio unit comprising:

a local frequency reference;

a closed loop control system including a loop filter for tuning the operating frequency of the radio unit to a received radio signal;

means for varying the characteristic of the loop filter during the processing of a signal from a given signal source to provide the closed loop control of the operating frequency, the varying means comprising:

means for arranging the loop filter to have a particular filter characteristic when a radio signal from a given source is first received;

means for, thereafter during the signal reception, changing the characteristic of the loop filter after each of N successive samples taken of the received radio signal, where N is an integer greater than zero; and

means for fixing the characteristic of the loop filter for the remainder of the reception from the signal source once the N signal samples have been taken.

25. A radio unit as claimed in claim 23 or 24, further comprising means for arranging the initial characteristic which the loop filter has when the signal is first received to have a predetermined value.

26. A radio receiver as claimed in claim 23, 24, or 25, wherein the means for changing the characteristic of the loop filter during the signal reception comprises means for progressively increasing the settling time of the system as the number of samples increases until N samples have been taken.

27. A radio unit as claimed in claim 23, 24, 25 or 26, wherein the means for fixing the characteristic of the loop filter provides a relatively slower settling time once the N samples have been taken.

28. A radio unit comprising:

a local frequency reference;

a closed loop control system including a loop filter for tuning the operating frequency of the radio unit to a received radio signal;

means for, when using the closed loop control system to tune the radio unit's operating frequency to a received signal, when a radio signal from a given source is first received, setting the loop filter's response characteristic so as to provide a first, more rapid, settling time characteristic for the closed loop control system;

means for changing the response characteristic of the loop filter so as to progressively increase the settling time of the system as the signal reception continues, until a predetermined number of signal

samples have been received; and

means for, thereafter, fixing the response characteristic of the loop filter at a setting that provides a longer settling time for the control loop.

29. A radio unit as claimed in any one of claims 23 to 28, further comprising means for deriving the filter characteristic set after each given one of the N successive samples taken from the received radio signal using a parameter derived from the current received signal sample.

30. A radio unit as claimed in any one of claims 23 to 29, further comprising means for setting the filter characteristic after each of the N successive samples taken from the received radio signal on the basis of the signal sample number.

31. A radio unit as claimed in any of claims 23 to 30, wherein the radio signal comprises discrete signal portions, and the receiver further comprises means for changing the characteristic of the loop filter after signal samples comprising such signal portions.

32. A radio unit as claimed in claim 31, further comprising means for assessing the signal quality of samples of the received signal, means for comparing the signal quality with a predetermined threshold value, and means for changing the characteristic of the loop filter only after signal samples corresponding to those signal portions whose signal quality exceeds, or alternatively equals or exceeds, the threshold value.

33. A radio unit as claimed in any one of claims 22 to 32, further comprising means for applying any correction derived for the operating frequency or the local frequency reference of the radio unit only when there is

a gap in the signal reception.

34. A radio unit as claimed in any one claims 22 to 33, further comprising means for determining whether the received signal is continuous, and

means for, when a continuous signal is detected, fixing the loop filter to have a characteristic providing a relatively slow settling time for the duration of the signal reception.

35. A radio transceiver comprising:

a local frequency reference;

a closed loop control system for tuning the operating frequency of the transceiver to a received radio signal; and

means for assessing whether the operating frequency reference of the radio transceiver is sufficiently closely aligned to the received radio signal to allow the transceiver to transmit by comparing the correction currently to be applied by the closed loop control system to a predetermined threshold correction value.

36. A radio unit as claimed in any one of claims 22 to 35, further comprising

means for storing the frequency offset derived to bring the receiver into alignment with a given signal source once the operating frequency of the receiver is tuned to that signal source and

means for, when the radio receiver returns to a signal source for which it has a stored settled frequency offset within a predetermined period of time since the stored frequency offset was derived, reapplying that stored frequency offset to its local frequency reference.

37. A radio receiver, comprising:

a local frequency reference;

means for storing the derived settled frequency offset which had to be applied to the local frequency reference of the receiver to bring it into alignment with a given signal source, once the receiver's operating frequency is satisfactorily tuned to that signal source; and

means for, when the radio receiver returns to a signal source for which it has a stored settled frequency offset within a predetermined period of time since the stored frequency offset was derived, reapplying that stored frequency offset to its local frequency reference, rather than deriving a new frequency offset for that frequency reference.

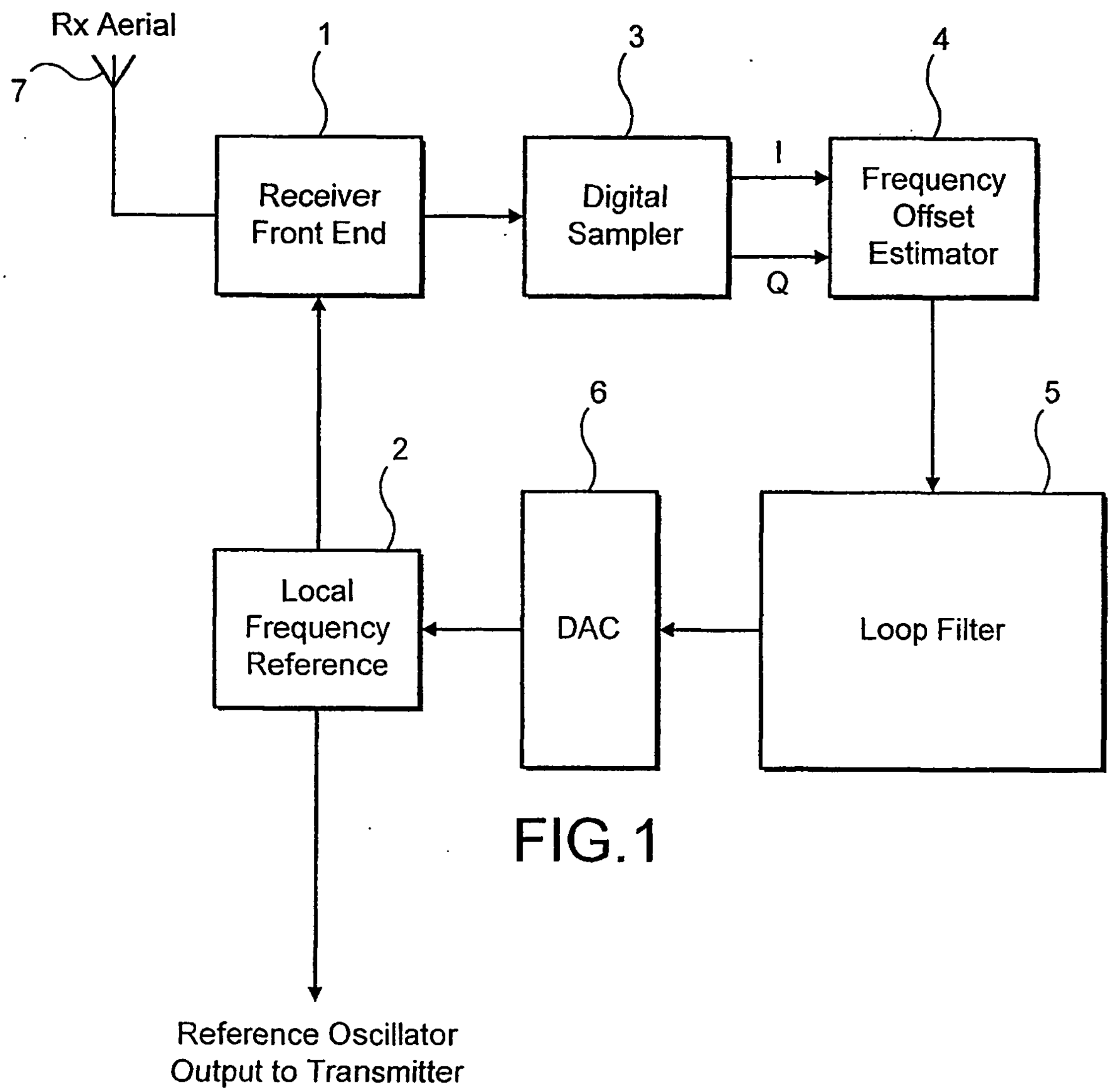
38. Computer software specifically adapted to carry out the method of any one of claims 1 to 21 when installed on a data processing means.

39. A radio unit in accordance with any one of claims 22 to 37, wherein the radio unit is a mobile unit of a mobile radio communications system.

40. A radio unit in accordance with any one of claims 22 to 37 wherein the radio receiver is a mobile unit of a TETRA system.

41. A method of operating a radio unit of a radio communications system, substantially as hereinbefore described with reference to the accompanying drawings.

42. A radio unit of a radio communications system, substantially as hereinbefore described with reference to the accompanying drawings.



Rx Aerial
7
1
3
4
Receiver Front End
Digital Sampler
I
Q
Frequency Offset Estimator
6
5
2
Local Frequency Reference
DAC
Loop Filter
Reference Oscillator Output to Transmitter


FIG.1

# INTERNATIONAL SEARCH REPORT

Int· ıal Application No
PCT/GB 01/00122

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 H03J7/04 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H03J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 5 659 884 A (QUIRE CHRISTOPHER S ET AL) 19 August 1997 (1997-08-19) | 1,15,16, 18-22, 33, 35-37, 39,40 |
| | column 7, line 54 -column 18, line 55; figures | |
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| X | US 5 740 525 A (SPEARS JOHN H) 14 April 1998 (1998-04-14) column 2, line 46 -column 6, line 10 column 7, line 40 -column 8, line 29; figures | 1,16,22, 33,39,40 |
| A | | 2-10,12, 13, 23-29,31 |
| | --- | |
| | -/-- | |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 14 May 2001 | 25.05.2001 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016 | Balbinot, H |

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 90 16113 A (ADVANCED SYSTEMS RESEARCH) 27 December 1990 (1990-12-27)<br><br>page 8, line 14 -page 20, line 35; figures | 1,16, 19-22, 33,36, 37,39,40 |
| P,X | WO 00 31870 A (ERICSSON INC) 2 June 2000 (2000-06-02) page 11, line 10 -page 33, line 25; figures 1-4 | 1,22,39 |
| P,A | | 2-10,12, 13, 23-29,31 |

INTERNATIONAL SEARCH REPORT

ational application No.
PCT/GB 01/00122

**Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 38
because they relate to subject matter not required to be searched by this Authority, namely:

Rule 39.1(vi) PCT

2. [X] Claims Nos.: 41,42
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

see FURTHER INFORMATION sheet PCT/ISA/210

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

Claims Nos.: 41,42

Rule 6.2(a) PCT.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Int·  ·nal Application No
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